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IONIZING RADIATION AND HUMAN BODY IN FUTURE MARS SPACE MISSIONS: CHALLENGES AND OPPORTUNITIES

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Abstract: Ionizing radiation represents one of the biggest biological limitations in human space missions. In our daily life, we are protected from most space radioactive sources thanks to the terrestrial atmosphere and geomagnetic field.

The aim of our research was finding the most important clinical consequences of exposure to ionizing radiation on astronauts' health during a typical Mars mission. These data mostly come from radiotherapy patients and survivors to nuclear accidents. In addition, we explored and analysed specific chemical compounds which might be implemented in astronauts' diets to improve their radioprotection during space missions.

Keywords: space radiation, radioprotection, vitamins, lipoic acid

1. MAIN EFFECTS OF IONIZING RADIATION ON HUMAN BODY

According to CDC, 0.7 Gy is the threshold dose for the onset of the acute radiation syndrome which might cause, depending on the radiation dose, nausea, vomiting, hematopoietic disorders, gastrointestinal diseases, or CNS health hazards. Therefore, astronauts may experience several clinical problems linked to the exposure to space radiation and one of the most common symptoms is *fatigue* which does not comply with astronauts' tasks during a space travel.

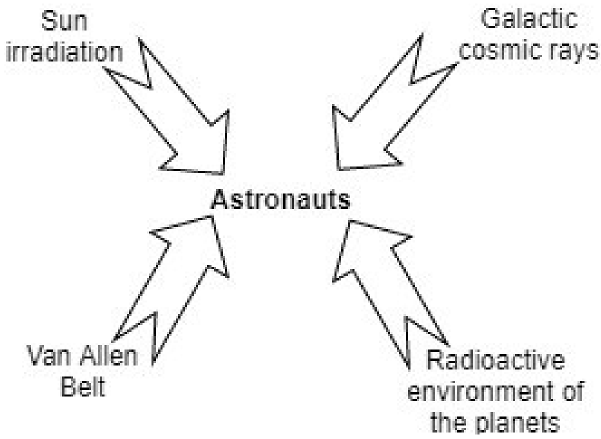

Figure 1: *Main radioactive sources in space missions.* Adapted from Cortese et al. (2018).

Cataracts, observed as a late effect of Chernobyl exposure to ionizing radiation, may have a higher incidence in astronauts. In fact, according to a 5-years study conducted by NASA (NASCA), the posterior subcapsular lens opacity happened to show statistically significant higher values than those for people who were exposed to a normal annual radiation dose.

At proton doses, as low as 0.5 Gy, bone loss might persist for 9 weeks after irradiation and, with 1 Gy doses, it can persist for up to 4 months. Solar Particle Events (SPEs) may have dangerous effects on human skeleton, leading to an increased fragility.

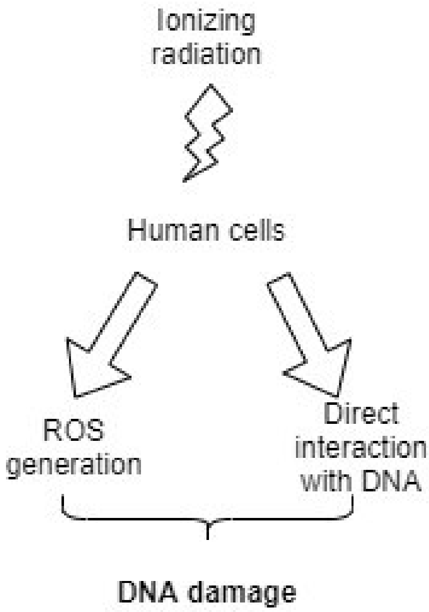

Figure 2: *Effect of ionizing radiation on DNA in human cells.* Adapted from Jeong & Jeong (2017).

Ionizing radiation has many consequences at an intracellular level (Figure 2), causing an initial peroxidation of membrane lipids. Also, there are both direct and indirect processes that lead to DNA damage. A direct pathway consists in the interaction with DNA backbone and nucleic bases, leading to strand breaks and mutations. The indirect pathway is based on water radiolysis, leading to the creation of Reactive Oxygen Species (ROS) that can interact in a second moment with DNA causing similar effects. It has been demonstrated in several articles, available in current literature, that high-LET radiation is more dangerous than equivalent doses of low-LET radiation.

2. DIETARY MITIGATION STRATEGIES

Re-shaping astronauts' diets may represent a fundamental tool which can be regulated to protect them from the radioactive risk in outer space:

- Vitamins = increase the quantity of antioxidant substances like beta-carotene and alpha-tocopherol.
- Peculiar food supplements = dried plum powder seemed to protect mice from bone loss after irradiation with low-LET gamma rays and a mixture of protons and HZE ions, simulating the space environment. Also, curcumin (extracted from turmeric), flavonoids (derived from tea, wine, leafy vegetables) and hydroxycinnamic acids (derived from fruits, vegetables, and cereals) show good antioxidant properties which may represent a potential intertwining between nutrition and space radioprotection.
- Probiotics = might prevent the dysbiosis that happens after intestinal microbiome is exposed to high-LET radiation doses.

In addition, specific pharmacological agents, such as lipoic acid (LA), can help regulate the cell redox potential along with vitamins C, E, and glutathione. Since it is usually inhibited by middle-chain fatty acids, it is recommended that lipoic acid is taken 30 minutes before or 2 hours after eating. DHLA, the reduced form of lipoic acid, can regenerate vitamin E and it is known to have strong antioxidant properties, interacting with biologically unstable chemical species such as singlet oxygen and hydroxyl radicals.

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